**The President's Vision for Space Exploration: Perspectives from a Recent NRC Workshop on National Space Policy**

Statement of

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before the

Committee on Science
U.S. House of Representative

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## Introduction

Chairman Boehlert, Ranking Member Gordon, and members of the committee, thank you for inviting me to testify today. My name is Lennard Fisk. I am the Thomas M. Donahue Collegiate Professor of Space Science at the University of Michigan, and I appear before you today in my capacity as the Chair of the National Research Council's Space Studies Board. In discussing the President's vision for space exploration this morning I will be telling you about a workshop that the National Research Council held last November under the sponsorship of the Space Studies Board and the Aeronautics and Space Engineering Board. The purpose of the workshop was to discuss the question: What should be the principal purposes, goals, and priorities of the U.S. civil space program? As I will tell you, there are many ideas from that workshop that are well embodied in the President's vision for space exploration. There are also some views on implementation, which you may wish to consider. There are, however, some notable differences from what participants at our workshop thought was an appropriate approach that I would like to call to your attention.

I have brought with me and would submit for the record a list of the workshop participants and a copy of the report,[1] titled *Issues and Opportunities Regarding the U.S. Space Program: A Summary Report of a Workshop on National Space Policy*, which summarizes our discussions. As you can see from the list, the participants represented a broad range of experiences in the space program, having participated in leadership positions in NASA, industry, and the military, as well as the science community. The discussions were informed and lively, and what impressed me most was the extent to which people agreed on the key issues.

## Is the President's Vision Needed?

The participants in the NRC workshop stated several times over the course of the meeting that NASA needed a clear vision, direction, and goal for the human spaceflight program. Furthermore, these participants were inclined to agree that such a goal should be the human exploration of the solar system beyond low-Earth orbit. They viewed exploration as the acquisition of new knowledge: knowledge of space as a place for human activity, knowledge of our solar system, and knowledge of the universe beyond our solar system. They also saw exploration as a basic human desire, innate in our genetic code, and noted that human space flight can be the modern realization of that basic trait.

## Is NASA Approaching the Vision Correctly?

The important question, of course, is how does the nation proceed in order to achieve a space exploration goal? How do we ensure success? Our workshop recognized that exploration of our solar system is a long-term endeavor, which needs to be accomplished with a series of incremental steps. In this sense, the human exploration efforts can learn

[1] *Issues and Opportunities Regarding the U.S. Space Program: A Summary Report of a Workshop on National Space Policy*, NRC Space Studies Board and Aeronautics and Space Engineering Board (2004)

from the successes of NASA's science programs. Workshop participants observed that certain key factors have contributed to the success of the science program: there are clear goals in the science program established by the science community's interest in pursuing the most challenging scientific questions; there is strategic planning; and there has been a steady sequence of accomplishments. The science program is executed via a series of individual steps that can accumulate success, from which progress can be measured and momentum sustained.

So what are these steps for human exploration? Our workshop participants envisioned a number of key efforts—the development of building block technology, the dedication of ISS research to solving questions posed by long-term spaceflight, eventual phasing out of the space shuttle, and the use of robotic precursor missions to both the Moon and Mars. These steps also are part of NASA's new roadmap for space exploration.

In 1997 the Space Studies Board published a report which I think offers several complementary ideas for a roadmap for space exploration. Titled *The Human Exploration of Space*, the report reviews three important areas of consideration that the Board felt were necessary to address at the initial stages of a program in human exploration.[2] First is the enabling science for human exploration. This defines the conditions necessary to maintain the health and safety of astronauts and to ensure their optimal performance. Research areas that are enabling science can be classified according to their degree of urgency. Critical research issues, or "showstoppers," are those for which inadequate scientific data lead to unacceptably high risks to any program of extended space exploration. The second area of consideration is the science that is enabled by a human exploration program, specifically human missions to the Moon and Mars. The third area of consideration is one of management and organization—what should be the relationship between the scientific community and NASA, between scientists and engineers within NASA, as a program of human exploration moves forward?

The 1997 SSB report identifies the following as those showstopper, critical research issues: the long- and short-term effects of ionizing radiation on human tissue; the radiation environment inside proposed space vehicles; the benefits and costs of different radiation shielding techniques; the detrimental effects of reduced gravity and transitions in gravitational forces on all of the body's systems and on bones, muscles, and mineral metabolism; and the psychological effects of long-duration confinement in microgravity with no escape possible. These and several other issues related to the human biological response to space exploration are detailed and prioritized in two more recent National Academies reports: *A Strategy for Research in Space Biology and Medicine in the New Century*,[3] published by the Space Studies Board; and *Safe Passage: Astronaut Care for Exploration Missions*,[4] published by the Institute of Medicine.

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[2] *The Human Exploration of Space,* NRC Space Studies Board, 1997

[3] *A Strategy for Research in Space Biology and Medicine in the New Century*, NRC Space Studies Board, 1998

[4] *Safe Passage: Astronaut Care for Exploration Missions*, Board on Health Sciences Policy, Institute of Medicine, 2001

As for the connection between scientists and engineers, I was struck at our workshop by how members of the scientific community appeared willing to embrace the idea that the human spaceflight program can be a contributor to real scientific progress. I think our participants would echo the conclusions of the 1997 report which called for an integrated science program to accompany human missions to the Moon and Mars, as well as the close coordination between human spaceflight and science program staff in the implementation of an exploration program. Participants at our workshop said many times that the reason the process of setting research priorities by the scientific community has had a positive impact on NASA's science programs is that it creates within the scientific community, a community that in the language of Congress can be considered the constituency of the science programs, a sense of ownership in the program. That feeling of ownership creates what we called a constructive tension between NASA and the science community, which ultimately empowers the program to excel. We observed this sense of ownership to be missing from the human spaceflight part of NASA, but that does not have to remain the case.

Robotic precursor missions to the Moon and Mars can provide an opportunity to engage this issue of cooperation between science and exploration, develop new technologies for space exploration, and significantly enhance and optimize the scientific return of eventual human missions. A 2002 report by the Space Studies Board, *New Frontiers in the Solar System: An Integrated Exploration Strategy*,[5] highlighted an extremely exciting opportunity for science from the Moon, by making a sample return mission to the Moon's South Pole-Aitken Basin one of its top priorities. By studying the internal structure of the Moon at this location, which is the oldest and deepest impact structure preserved on the Moon, we can investigate how major impacts on the Earth from early solar system space debris shaped the evolution of our planet. The solar system exploration strategy report also identifies important scientific opportunities for the exploration of Mars.

Participants at our workshop argued that precursor missions to the Moon and Mars should seek to move past a previously long-standing dichotomy that has existed between robotic and human spaceflight over most of NASA's existence. Part of the goal of these missions should be to develop the technology that will allow for the greatest possible human-robotic interaction. Workshop discussions emphasized the concept of synergy—not just complementarity—between robots and humans. We must learn how to best take advantage of the strengths of both, separately and in cooperation.

## Further Comments on Science

There are other critical research challenges which deserve equal attention and consideration in addition to the biological and physiological questions I mentioned. Specifically, I refer to two issues highlighted in our 1997 Human Exploration report: (a) the characteristics of cosmic-ray particles and the extent to which their levels are modulated by the solar cycle and (b) the frequency and severity of solar flares. These issues arise from questions about the nature of the role of the Sun in our solar system and

[5] *New Frontiers in the Solar System: An Integrated Exploration Strategy*, Space Studies Board, 2002

how the Sun creates and controls the environment into which we intend to send astronauts. The recent NRC decadal science strategy for solar and space physics[6] identified key missions within NASA's Sun-Earth Connections program that are critical to understanding these fundamental processes and consequently to understanding the volatile space environment. That report recommended that the Sun-Earth Connections program of NASA be charged with, and provided the resources needed for, developing a predictive understanding of the Sun and the space environment it controls. I would urge you to carefully consider the impact of any prioritization that would hinder or delay the development of our understanding of and our ability to predict the space environment.

## A Lack of Balance in the Science Programs

It was the opinion of many at our workshop that the science road maps, decadal strategy surveys, and mission plans in astronomy and astrophysics, solar and space physics, and solar system exploration, which have been so carefully developed by scientists and engineers in the external community and in NASA, and NASA's careful attention to these details in execution of its programs, have resulted in science being NASA's greatest current strength. In fact, since the Apollo era came to a close one might argue that NASA's science efforts have been responsible for a major fraction of the Agency's greatest successes. The pertinent question then is: Can NASA preserve the strengths of its science programs and at the same time energize a new human spaceflight program that seeks to include the science of exploration as part of an overall new thrust for the agency?

This is, of course, a question of balance—balance between a new exploration priority and continuing successful science programs. I would encourage you to consider whether or not the science disciplines have been divided unnecessarily into those that are *perceived* as essential for exploration and those that are not. Our reports argue that the sun and the planets and moons of the solar system are all equally worthy of exploration. They also suggest that research to study both the origins of planetary systems and life and the structure and evolution of the universe are highly important.[7] In Earth science, NASA has a responsibility under the Space Act and its amendments to use its capabilities to understand our home planet and predict its future. While NASA may now have a priority to explore, I would expect that it still also has the responsibility to deliver to the policy makers and the public a sufficient understanding of how we can be good stewards of our planetary home.[8]

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[6] *The Sun to the Earth--and Beyond: A Decadal Research Strategy for Solar and Space Physics*, NRC Space Studies Board (2002).

[7] The relation of this research to exploration in its broadest context is addressed in *Astronomy and Astrophysics in the New Millennium*, National Research Council (2000) and *Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century,* National Research Council (2000).

[8] The importance of NASA's Earth science program is addressed in *Assessment of NASA's Draft 2003 Earth Science Enterprise Strategy*, NRC Space Studies Board (2003).

## How to Move Forward

The matter of balance between new exploration priorities and science opportunities, between new priorities and responsibilities, is very difficult to tackle. I believe the best way to approach this matter, as is emphasized in our workshop report, is to move forward on the human exploration front at a deliberate pace. Our workshop discussions embraced the idea that NASA should pursue a long-term goal via a series of small steps, and they identified *learning* as *the* critical factor that should drive implementation decisions.

There are several subjects about which we need to learn more. We must learn about the technology we will employ in this endeavor. We must learn more in several areas before we can be sure we have minimized the health risks to astronauts. And all of us, the scientific community, NASA, the Congress, and the nation as whole, must learn how to organize our space program to engage this effort. The workshop report describes concerns that the infrastructure of our space program was formed and sized to support Apollo and it asks "Is the current infrastructure properly configured for a bold initiative?" The report notes that the space program workforce, in the broadest sense, is aging; the attitudes seem risk averse; process seems more important than ingenuity. Can this mind-set be changed? An aging workforce and infrastructure is also a feature of the space science community. Where are the bold new minds that will lead us into the future?

Finally, there is the matter of cost. A sense at the workshop was that it is too premature to estimate how much an exploration initiative would cost—exactly because we have a great deal to learn and because our past experiences have told us that we should be careful in estimating costs too early. This is at the heart of why our participants emphasized a deliberate approach—we should identify critical research and technology development issues and devise, even at this early time, some kind of roadmap for progress in those areas. We must also examine the full breadth of NASA's science programs to determine what research already *underway* may contribute to that progress; what research is currently *planned* that may contribute to that progress; and what *new* research is necessary, and we must support them all with the resources necessary to achieve success. Only through this balanced approach, with roadmaps for technology development and scientific progress that are related to each other and flexible enough to adapt to change and to learning can we have a guidepost against which we measure our progress, articulate our successes, and identify our next steps.

This approach to success through a series of individual steps implies a kind of "go-as-you-pay" approach to exploration to allow for affordable and flexible exploration that changes in response to learning. In this sense then, go-as-you-pay is complemented by the practice of pay-as-you-learn.

## Conclusion

In closing, Mr. Chairman, I would like to again thank you for inviting me to testify today. I would be happy to address any questions you and the committee may have about our report or the discussions that took place at our workshop. A renewed opportunity for human exploration in the solar system creates an exciting moment in our nation's history.

I can tell you that there is indeed great excitement in the space community, which I believe is reflected in our report. I think further that the leaders of the scientific community may be ready to stand up and say “we believe this country should invest in this activity, and we are ready to make the case to the world that this is a valid use of this nation’s resources.” I am hopeful that we as scientists are ready to engage this process actively to help guide its implementation and direct it toward success.

**NRC Space Policy Workshop Participants**
**November 12-13, 2003**

**PANELISTS**

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Robert Frosch, Harvard University
Riccardo Giacconi, Johns Hopkins University and University Research Associates
Noel Hinners, Lockheed-Martin (retired)
Wesley Huntress, Carnegie Institution of Washington
Thomas D. Jones, Consultant
Todd R. La Porte, University of California, Berkeley
John Logsdon, George Washington University
Richard Malow, AURA
Howard McCurdy, American University
Norman Neureiter, Texas Instruments (retired), Department of State through September 2003
Mary Jane Osborn, University of Connecticut Medical School
Robert Richardson, Cornell University
Edward C. Stone, California Institute of Technology, U.S. Representative to COSPAR
J.R. Thompson, Orbital Sciences Corporation
Albert Wheelon, Hughes Aircraft Company (retired)

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Ana P. Barros, Harvard University
Reta F. Beebe, New Mexico State University
Roger D. Blandford, Stanford University
James L. Burch, Southwest Research Institute
Radford Byerly, Jr., University of Colorado
Howard M. Einspahr, Bristol-Myers Squibb Pharmaceutical Research Institute (retired)
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Michael H. Freilich, Oregon State University
Donald Ingber, Harvard Medical School
Ralph H. Jacobson, Charles Draper Laboratory (retired)
Tamara E. Jernigan, Lawrence Livermore National Laboratory
Margaret G. Kivelson, University of California, Los Angeles
Bruce D. Marcus, TRW, Inc. (retired)
Harry Y. McSween, Jr., University of Tennessee
Dennis W. Readey, Colorado School of Mines
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Mitchell Sogin, Marine Biological Laboratory
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Donald L. Cromer, United States Air Force (retired) and Hughes Aircraft Company (retired)
Dava J. Newman, Massachusetts Institute of Technology

**INVITED GUESTS**

Bill Adkins, House Committee on Science
Marc S. Allen, NASA Headquarters, Office of Space Science
Andrew Christensen, The Aerospace Corporation, chair, Space Science Advisory Committee
John Cullen, Senate Commerce Committee
Gerhard Haerendel, International University, Bremen, ESSC Chair
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## Biographical Information

LENNARD A. FISK, chair of the Space Studies Board of the National Research Council, is the Thomas M. Donahue Collegiate Professor of Space Science in the Department of Atmospheric, Oceanic, and Space Sciences at the University of Michigan. He is an active researcher in both theoretical and experimental studies of the solar atmosphere and its expansion into space to form the heliosphere. He heads the Solar and Heliospheric Research Group, which develops new theoretical concepts and models, analyzes data from the ongoing Ulysses, WIND and ACE missions, and which constructs new flight hardware for upcoming missions such as the MESSENGER mission to Mercury. From 1987 to 1993, Fisk was the Associate Administrator for Space Science and Applications and Chief Scientist of NASA. In that position he was responsible for all of NASA's science programs, including space science, Earth science, and microgravity life and physical sciences. From 1977 to 1987, Fisk served as Professor of Physics and Vice President for Research and Financial Affairs at the University of New Hampshire. Concurrent positions include Chairman of the Board of Trustees of the University Corporation for Atmospheric Research, member of the Board of Directors of the Orbital Sciences Corporation, and co-founder of the Michigan Aerospace Corporation. Fisk is a member of the National Academy of Sciences.